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09/743,982	01/18/2001	Takao Abe	108360	1567

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EXAMINER

ANDERSON, MATTHEW A

ART UNIT PAPER NUMBER

1765

DATE MAILED: 10/27/2003

23

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary

Application No.

09/743,982

Applicant(s)

ABE ET AL.

Examiner

Matthew A. Anderson

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-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 22 July 2003.
- 2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 20-22, 24 and 27-49 is/are pending in the application.
- 4a) Of the above claim(s) _____ is/are withdrawn from consideration.
- 5) ☐ Claim(s) _____ is/are allowed.
- 6) ☒ Claim(s) 20-22, 24 and 27-49 is/are rejected.
- 7) ☐ Claim(s) _____ is/are objected to.
- 8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☒ The drawing(s) filed on 01 February 2001 is/are: a) ☒ accepted or b) ☐ objected to by the Examiner.
- Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
- 11) ☐ The proposed drawing correction filed on _____ is: a) ☐ approved b) ☐ disapproved by the Examiner.
- If approved, corrected drawings are required in reply to this Office action.
- 12) ☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. §§ 119 and 120

- 13) ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☒ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☒ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).
- * See the attached detailed Office action for a list of the certified copies not received.
- 14) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).
- a) ☐ The translation of the foreign language provisional application has been received.
- 15) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Attachment(s)

- 1) ☒ Notice of References Cited (PTO-892) 4) ☐ Interview Summary (PTO-413) Paper No(s). _____
- 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) 5) ☐ Notice of Informal Patent Application (PTO-152)
- 3) ☒ Information Disclosure Statement(s) (PTO-1449) Paper No(s) 18, 19. 6) ☐ Other: _____

DETAILED ACTION

Claim Rejections - 35 USC § 103

1. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

2. This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

3. Claims 20- 22, 24, 27-29, 32-49 are rejected under 35 U.S.C. 103(a) as being unpatentable over Minahan et al. (Conf. Rec. IEEE Photovoltaic Spec Conf. (1982), 16th, 310-15) in view of Wolf et al. (Silicon Processing for the VLSI Era Volume 1: Processing Technology, Lattice Press, Sunset Beach, CA, USA, pp. 1-35, 1986.).

Minahan et al. discloses the use of Gallium doped and Boron doped FZ and CZ silicon in solar cells. The purpose of the study was to determine the effect of 1MeV electrons on the spectral response of various cells before and after such radiation bombardments (see abstract). Ga doped silicon was known to improve the radiation tolerance of gallium doped silicon. Oxygen and carbon were known to have a direct role in radiation tolerance. (1st col. Page 310). Ga doped Si grown by the Cz (Czochralski) method were used at a concentration of 0.1 Ω -cm and 10 Ω -cm in the test. These Cz crystals were grown with boron and phosphorous content of less than 2.0 ppba and less than 1.0 ppba, respectively. (col. 2 page 310). Other methods of growing single crystal Si were used in the tests such as Fz (float zone) and a modified Cz using a cold crucible made of solid Si to reduce oxygen contamination (col. 2 page 310). Fz silicon with resistivity at 0.1, 1 and 10 Ω -cm were used. Cold crucible Cz Si resistivities were 0.9 and 12 Ω -cm. The reference of Minahan et al. succeeds at disclosing a gallium doped single crystal, suitable for use in solar cells, produced according to the Czochralski method with resistivity overlapping that claimed by applicants.

Several differences are noted between the teachings of Minahan et al. and applicants claimed invention. Minahan et al. does not explicitly disclose solar cells made from single crystal wafers of 4 inches or more. In addition, Minahan et al. is silent about the specific gallium concentration in the disclosed crystals.

Wolf et al. discloses the known technology of silicon single crystal formation and doping. Typical interstitial oxygen concentrations in Cz-Si are given as 5×10^{17} - 1×10^{18}

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atoms /cm³ on page 16. Diameters for typical Cz-Si wafers formed from single crystal ingots are given as up to 200mm (~8 inches) on page 27. Formation of wafers from Si single crystal ingots by slicing is disclosed on page 23. The direct relationship of resistivity (Ω -cm) to impurity doping concentration (atoms/cm³) is shown in Fig. 22 on page 28. The means of converting ppma to impurity concentration is found on page 5.

Since the Cz Ga-doped Si crystal of Minahan et al. is suitable for use in solar cells, it would have been obvious to one of ordinary skill in the art at the time the invention was made to produce a Cz Ga-doped Si crystal having a 4" or more diameter because the reference of Wolf et al. discloses that Cz Si crystals with 4" or larger diameters are conventional. In addition, one of ordinary skill would also be motivated to select a diameter of 4" or more in order to desirably provide more surface area for solar cell formation of radiation tolerant doped Si.

It would have been obvious to one of ordinary skill in the art at the time of the present invention to combine the references because Wolf et al. discloses common sizes of Cz Si ingots and Minahan discloses solar cells made from wafers cut from Cz Si ingots. Motivation for the combination stems from the fact that larger ingots would provide more surface area for solar cell formation of radiation tolerant gallium doped Si.

In respect to claim 21, it would have been obvious to one of ordinary skill in the art at the time of the present invention to select a Ga impurity concentration of from 5×10^{17} /cm³ to 3×10^{15} /cm³ in the Cz Si crystal of Minahan et al. because these impurities were seen from Wolf's Fig 22 to be approximately equivalent to having a desired resistivity in the range from 0.1 Ω -cm to 5 Ω -cm since one of ordinary skill knows that

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the added impurity concentration is the cause of the obtained resistivity (i.e. the resistivity seen in the Si is directly related to the amount of dopant added), and one of ordinary skill would add a specific impurity concentration to obtain/control a desired resistivity.

In respect to claim 22, it would have been obvious to one of ordinary skill in the art at the time of the present invention to expect Cz-Si of Minahan et al. to have a interstitial oxygen concentration of 2.0×10^{18} atoms/cm³ or less because such is described as a typical range for Cz-Si by Wolf et al.

In respect to claim 24, it would have been obvious to one of ordinary skill in the art at the time of the present invention to produce wafers by slicing silicon single crystals because both Minahan (col. 2 page 311) and Wolf et al. (page 23) at least suggest such wafer formation from single crystal Si ingots.

In respect to claims 27 and 28, it would have been obvious to one of ordinary skill in the art at the time of the present invention to form a solar cell from the sliced single crystal Si wafer because such is disclosed by Minahan et al. in col. 2 page 311.

In respect to claim 29, it would have been obvious to optimize the area of a solar cell produced from such doped Si wafers because a larger area means more light collection surface and thus more electron flow and because the known Si-wafer diameters from Wolf et al. (at least the 6 in and 8 in sizes) would have provided at least this much area.

In respect to claim 32, it would have been obvious to one of ordinary skill in the art at the time of the present invention to use a Si solar cell in space from news releases

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about the International Space Station, Minahan et al.'s disclosure of the measurement and analysis of radiation resistance in various Si solar cells, and because such a cell would have been anticipated to produce an expected result. The intended use has little effect on the determination of patentability for products.

In respect to claims 37, 46-47, It would have been obvious to one of ordinary skill in the art at the time of the present invention to use the Cz method of pulling Ga doped Si single crystals using a seed dipped into a rotated melt and doped to have both the claimed gallium impurity concentration and a resultant resistivity and diameter 4 inches or more because such constitutes the art known Cz method of forming Si single crystals as described by Wolf et al. and Minahan et al. discloses Cz grown gallium doped Si single crystals with utility for solar cells. (Minahan et al. describes the Cz as doped with Ga although the starting material had a nominal content of boron and phosphorus.)

In respect to claim 38, it would have been obvious to one of ordinary skill in the art at the time of the present invention to dope the melt by charging the crucible with a Si single crystal highly doped with Ga and forming a melt therefrom because such is suggested by Wolf et al. on page 12, 2nd paragraph.

In respect to claim 39, it would have been obvious to one of ordinary skill in the art at the time of the present invention optimize the rotation rate of the crucible because such rotation was described by Wolf et al. on page 15 to effect the chemical uniformity and thermal symmetry, such optimization would have been anticipated to produce an expected result of a more uniform melt, and such optimization would have been achieved with only routine experimentation.

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In respect to claim 40-42, it would have been obvious to one of ordinary skill in the art at the time of the present invention to optimize the pressure during the Cz growing process and the amount of argon gas flowed through the pulling apparatus because Wolf et al. discloses reduced pressure during growth for reducing contamination of the melt and the control of argon gas flow (page 18 with argon gas shown in Fig. 14), such optimization would have been achieved with only routine experimentation, and would have been anticipated to produce an improved Cz-Si ingot.

In respect to claims 43-45, it would have been obvious to one of ordinary skill in the art at the time of the present invention to optimize the resistivity of the silicon single crystal because resistivity was known to depend on the result effective variable of dopant impurity concentration present in the crystal, Minahan et al. disclosed such Ga concentrations in single crystal within the claimed range, and because such optimization would have been achieved with only routine experimentation.

In respect to claim 48 and 49, it would have been obvious to one of ordinary skill in the art at the time of the present invention to use the gallium doped Cz Si claimed as a solar cell because Minahan et al. discloses the utility of such a material in solar cells for resisting radiation damage.

In respect to claims 33-36, it would have been obvious to one of ordinary skill in the art at the time of the present invention, without evidence to the contrary, to conclude that the Ga doped Cz Si wafer having the other properties the same as the applicant's invention would have also had a very similar low loss of conversion efficiency due to photo-degradation because the applicant has described no special Cz pulling

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techniques required to obtain such a low loss if conversion efficiency due to photo-degradation and Minahan et al. describes Ga-doped Si as having improved radiation tolerance.

4. Claims 30-31, are rejected under 35 U.S.C. 103(a) as being unpatentable over Minahan and Wolf et al. as applied to the claims above and further in view of Wettling et al. (US 6,147,297).

Minahan and Wolf et al. combined are described above.

The combination does not explicitly disclose a solar cell conversion efficiency of over 20%.

Wettling et al. discloses a solar cell manufactured to form a surface texture. In col. 1 lines 25-35 it is disclosed that high efficiency solar cells are commonly formed from Si and attain efficiencies over 20%.

It would have been obvious to one of ordinary skill in the art at the time of the present invention to combine the radiation tolerant Si material of Minahan with Wettling et al.'s structure to form high efficiency and high radiation tolerant solar cells because such would last longer and be more efficient.

In respect to claims 30-31, it would have been obvious to one of ordinary skill in the art at the time of the present invention to form high efficiency solar cells because such cells have the lowest loss due to conversion of light into electricity (col. 1 line 30-35).

Response to Arguments

The applicants declarative argument in paper 17 in paragraph 7 that the conversion efficiency of over 20% for Ga doped Si was unexpected is not convincing. Wettling et al. discloses generically doped Si solar cells with comparable conversion efficiencies and there is not evidence that such efficiencies would have been achieved with Ga as the dopant.

The applicant's declarative argument in paragraph 8 is not convincing. The range described is within the range of resistivities known in the art. Cz crystals were produced by Minahan et al. for the express purpose of use in a solar cell at the low resistivity (i.e. high dopant concentration) endpoint of that range. Additionally, point within the range were also known for use as solar cells including 0.9 Ω -cm attained in the cold crucible Cz Si.

The applicant's arguments of paper 16 filed on 6/4/2003 and paper 22 filed on 7/22/2003 are noted but are largely moot in view of the new ground(s) of rejection presented in paper 23.

The examiner will respond to arguments directed to the currently cited references below.

The argument that the individual references do not disclose the claimed invention exactly is not in contention. However, the examiner does contend that the combination of references discloses known aspects of the Cz formation of Si crystals including Ga

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doping, size possibilities, resistance as related to the dopant concentrations, and the known use of Ga doped Si as solar cell components. Minahan discloses Ga doped Cz Si for solar cell uses. See the newly presented rejection above.

The argument against Wolf et al. is not convincing. Wolf et al. teaches general principles concerning Si Cz growth that one of ordinary skill in the art at the time of the present invention would have seen as conventional.

The argument concerning unexpected results are not convincing in light of Wettling et al. in that it was known to form Si based solar cells of certain geometries with efficiencies over 20%. Gallium was known to have utility as a dopant for Si solar cell single crystal material and, without evidence to the contrary, would have been expected to provide similar results. The cited resistivities were known and used in the art and merely depend on dopant impurity concentration added intentionally to the single crystal precursor material. In light of Wettling et al., the criticality of the range within the Minahan et al. resistivity range is not persuasive.

The argument that the secondary considerations establish the patentability of the claimed invention is not persuasive. Again, the resistivity range as well as the efficiency of Si-based solar cells with those resistivities was suggested by the art as presented above. The examiner notes the PVSEC-11 paper but cannot ignore the references since that conference is not ultimately responsible for United States patentability determinations in this matter. Minahan et al. suggests Ga as a contributor to increasing radiation tolerance in Si based solar cells.

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The argument against Minahan et al. and further that it teaches away from Cz gallium doped Si for solar cells is not persuasive. The argument is confusing in that Minahan et al. make solar cells from Cz crystals which would have been expected to have oxygen in them by the very nature of the Cz process. It did not stop Minahan from producing such solar cells. There is simply no implication in Minahan that $10\Omega\text{-cm}$ "is good enough" for solar cells since a broad range of resistivities was tested. Minahan is a test of tolerance of radiation in variously doped Si solar cells (col. 1 page 310). The specific gallium concentration are implied by the resistivity since these are directly related as per Wolf et al. Fig. 22.

The examiner has not cited Schmidt.

The lack of motivation argument is not persuasive since there is a new grounds of rejection along with definitive motivation statements above.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Matthew A. Anderson whose telephone number is (703) 308-0086. The examiner can normally be reached on M-Th 7:30-6.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Nadine Norton can be reached on (703) 305-2667. The fax phone numbers

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for the organization where this application or proceeding is assigned are (703) 872-9310 for regular communications and (703) 872-9311 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (703) 308-0661.

MAA
October 20, 2003

Matthew Anderson
A.U. 1765

NADINE G. NORTON
PRIMARY EXAMINER
Nadine